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CERL'S PROJECTILE IMPACT TESTING FACILITY

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CANADIAN EXPLOSIVES RESEARCH LABORATORY

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by

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ABSTRACT

The Canadian Explosives Research Laboratory (CERL) routinely tests commercial explosives to projectile impact to determine their relative sensitivity to such a stimulus. This report describes the new equipment used to perform such tests.

Keywords: projectile impact, explosives sensitivity, projectile velocity, commercial explosive testing, universal receiver.

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INSTALLATION D'ESSAIS D'EXPLOSIFS SOUS LE CHOC DE PROJECTILES AU LCRE

par

E. Contestabile*, T.R. Craig**, et P. Larsen***

RÉSUMÉ

Le Laboratoire canadien de recherche sur les explosifs soumet régulièrement des explosifs commerciaux à des essais sous le choc d'un projectile dans le but de déterminer leur sensibilité relative à un tel choc. Le présent rapport contient une description du nouvel équipement utilisé pour effectuer ces essais.

Mots-clés: impact du projectile, sensibilité des explosifs, vitesse du projectile, essais d'explosifs commerciaux, récepteur universel.

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CONTENTS

	Page
ABSTRACT	i
RÉSUMÉ	ii
INTRODUCTION	1
THE NEW TEST EQUIPMENT	1
The Gun	1
Velocity measurement	2
THE EXISTING FACILITIES	3
Experimental Site	3
Cartridge Loading Facility	3
EXPERIMENTAL PROCEDURE	5
The Explosive Sample	5
Testing Levels	5
Data Treatment	5
BIBLIOGRAPHY	8

FIGURES

No.		
1.	New projectile testing equipment	2
2.	Modified barrel	2
3.	Cross-section of detectors	2
4.	Detectors and projectile deflectors mounted on aluminum channel	3
5.	Sketch of test site	3
6.	Inside of tank as seen from the door opening	4
7.	Projectile specifications	4
8.	.50 cal round (primer, cartridge, propellant, kapoc, projectile)	4
9.	Priming the cartridge case	4
10.	Filling cartridge case with powder	4
11.	Crimping the projectile to the cartridge case	5

TABLES

1.	Testing levels presently used for projectile testing	6
2.	Statistical constants from reference (10) used to determine the V-50	6
3.	Values for the constants A and C, from reference (10), used to estimate the V-50 when N is greater than 6	6

CERL'S PROJECTILE IMPACT TESTING FACILITY

INTRODUCTION

The Canadian Explosives Research Laboratory (CERL), is responsible for evaluating and recommending for authorization under the Canada Explosives Act, commercial explosives manufactured, imported and sold in Canada. To do so, the laboratory subjects each sample submitted to extensive physical (1) and chemical tests. One such test is projectile impact.

Initially, this test was conducted using a standard .30 cal sporting rifle. Reference (2) details the testing procedure and the experimental work dealing with the sample's temperature, size and configuration. Tests were also performed with different bullet weights and configuration. The sensitivity of an explosive to bullet impact was then determined by shooting at ten, 500 g samples and recording the number of fires. In this fashion, a list of relative sensitivities of commercial explosives was established.

From a scientific view, the shape of the bullet presented too many variables and 'constant' bullet velocity made the test very restrictive. It was thus decided to use a solid brass, right cylindrical projectile having a well defined frontal area. The size decided upon was 1.30 cm in diameter and 1.27 cm in length. These projectiles were fired from a Canadian Forces Machine Gun, Browning, .50 cal M2 HB (Heavy Barrel). The gun was installed on a mount having pivot points about two perpendicular axes for the purpose of aiming. By varying the powder and load it was possible to fire at speeds ranging from 250 m/s tol600 m/s. Two Oehler Research Skyscreens (3), set 2 m apart and about 15 cm below the path of the projectile were used to start and stop an electonic counter to determine the time of flight and the corresponding projectile velocity. Reference (4) details the extensive work performed with this equipment.

The Browning machine gun performed well for many years, however, as explosives less sensitive to physical impact were produced, it became necessary to perform tests at the higher end of the velocity range. Such use led to the eventual failure of this gun. Since it was no longer possible to obtain the same machine gun, it was replaced with a different model. It, however, was found to be rather unreliable and a decision was made for a complete overhaul of the projectile impact testing equipment.

THE NEW TEST EQUIPMENT

The Gun

The most recent modification was intended to produce equipment that was sturdy and dependable and allowed adaption of the .50 cal machine gun heavy barrel from which modified rounds could be fired. At the time of this exercise, CERL's sporting ammunition testing facility also required overhauling. A search and design exercise was thus undertaken to find a solution to both requirements.

A decision was made to copy the breech of a German 37 mm Pak (single-shot, anti-tank gun), manufactured by Rheinemetall in 1935. After accurate drawings of the mechanism were made, three complete units were manufactured (5). One of the units was designed as a universal receiver while the other two were for stationary and mobile projectile impact testing facilities.

Slight modifications were made and certain parts were omitted from the original design for the purpose of simplifying manufacture and making the equipment safer to operate. For example, the cartridge extractor was omitted and a mechanism was incorporated for firing the unit from a remote location.

The unit was mounted on a steel plate and had a vertical adjustment. The plate was mounted in a steel guide and held in place by two flats. By varying the clamping load on the flats, the recoil of the receiver was easily controlled. The guide was, in turn, mounted on a base that had very finevertical and horizontal alignment capabilities for the purpose of aiming the gun. Figure 1 shows the complete unit mounted on a concrete base with the barrel installed. A keyed,

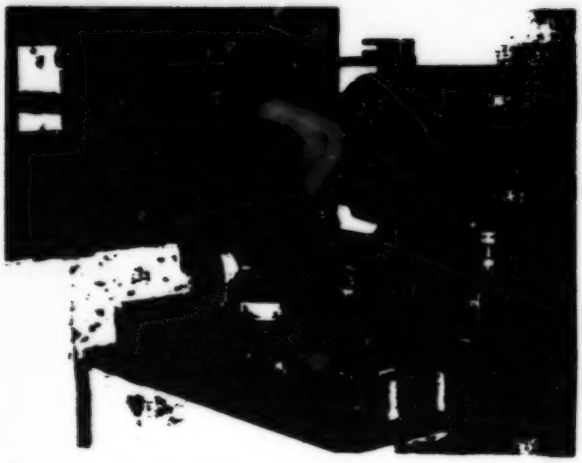

Fig. 1 - New projectile testing equipment

electrically actuated, solenoid valve is used to fire the gun via a pneumatic cylinder. This configuration allows the firing to be performed from a remote location away from the noise and fumes.

The heavy barrel from the machine gun was only slightly modified in the external area of the chamber end. Basically, a heavy steel collar was added for the purpose of holding the barrel captive in the receiver with the use of a large retaining nut. Figure 2 shows the machine gun's heavy barrel. A conformal type quartz transducer (6) was then installed in the chamber area to monitor the pressure at the different powder loads. The pressure detecting face of this transducer conforms to the chamber surface. When a round is fired, the pressure is transmitted through the cartridge case to be detected by the transducer. The signal from the transducer is then fed through an amplifier and recorded on a peak reading meter and a digital oscilloscope.

Fig. 2 - Modified barrel

Velocity Measurement

The system used for measuring projectile velocitieshas also been fully redesigned. Reference (7) describes this system in detail. It is basically comprised of two detectors set 2 m apart that determine the transit time of the projectile over the fixed distance by starting and stopping a clock. Each detector is composed of a series of photoelectric transistors that are able to detect the shadow of a projectile passing over their line of sight with ambient light conditions. Figure 3 shows a cross-section of a detector. The detectors, as shown in Fig 4, are mounted onan aluminum channel that can be positioned anywhere between the gun and target. In the figure, heavy steel deflectors can be seen mounted in front of each detector to protect against stray projectiles.

The electronic instrumentation will automatically displaythevelocity of the projectiles in the properunits. The display is held until the unit is reset.

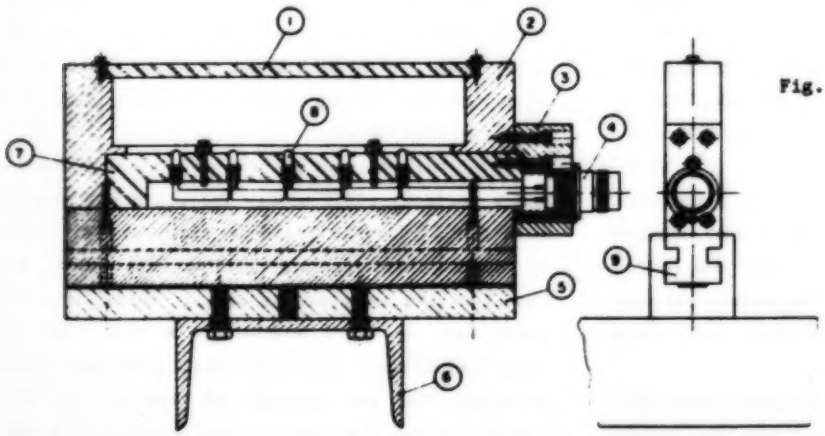

Fig. 3 - Cross-section of detectors

PROJECTILE DETECTOR PARTS LIST

1. Plastic window
2. Aluminum case
3. Aluminum block
4. Electrical connector
5. Brass base
6. Aluminum channel
7. Delrin detector holder
8. Detector (Q-ty 5)
9. Aluminum slide

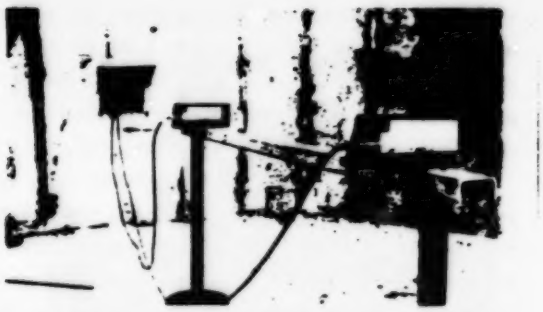

Fig. 4 - Detectors and projectile deflectors mounted on aluminum channel

THE EXISTING FACILITIES

Experimental Site

A sketch of the test site is shown in Fig 5. The gun is aimed at an opening on the door of a steel tank 2.5 m in diameter and 7 m long, that is buried in a mound of soil. A 50 cm diameter smokestack, 6m high, is mounted toward the back of the tank for purging the gases evolved during an explosion.

The explosive sample is hung, in the path of the projectile's trajectory, by a chain suspended from the top of the tank. This configuration, places the sample of explosive 32 m from the gun's muzzle.

When the explosive charge detonates, a loud report is heard, the tank fills with smoke, and the spring-loaded entrance door opens. The generated smoke then quickly begins to move out the smokestack. Figure 6 shows the inside of the tank as seen from the opening.

Cartridge Loading Facility

The projectiles used in these tests have been made from free-cutting brass stock to the specifications shown in Fig 7. By shooting at a paper target and observing the holes made by the projectile, it was found that the projectile was very stable in its path. This indicates that the projectile's frontal area was always parallel to the front face of the sample, thereby resulting in planar impacts.

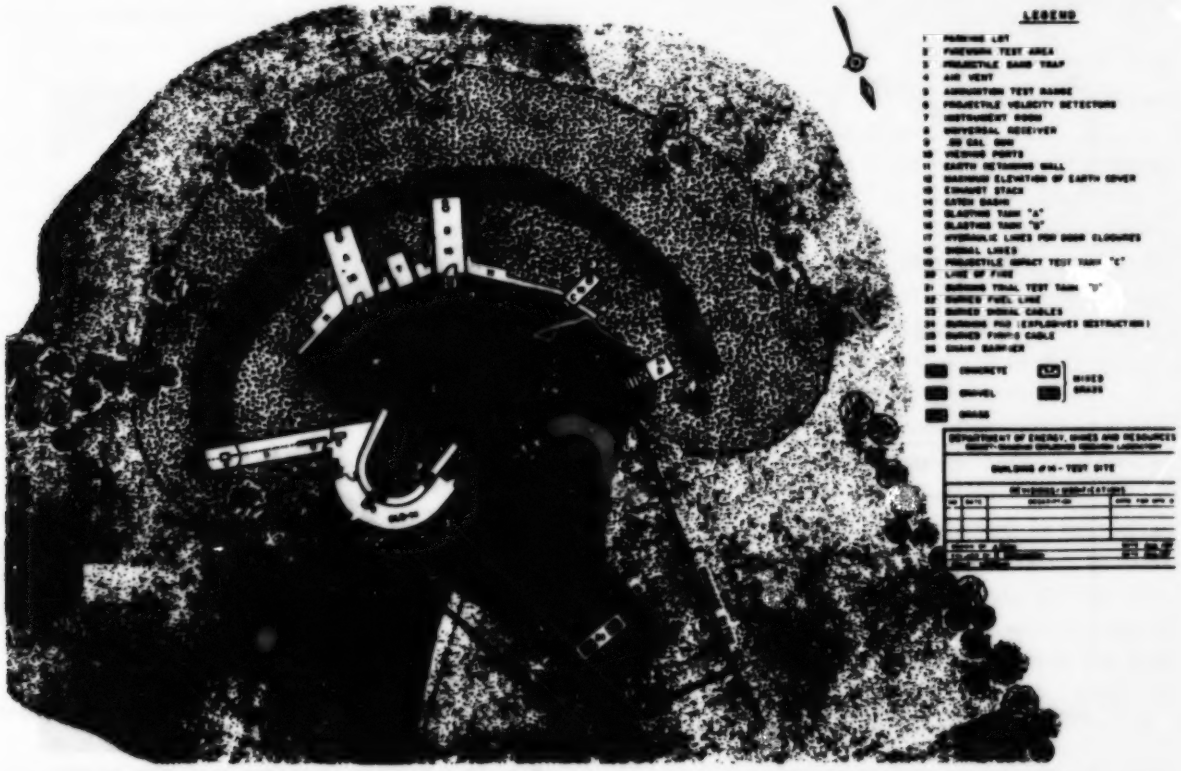

Fig. 5 - Sketch of test site

Fig. 6 - Inside of tank as seen from the door opening

The cartridge used in this projectile test is a standard .50 cal cartridge, with a 10 cm long case. These cartridges were initially purchased primed (8) and have been reused as often as ten times without any problems. The primed cases are loaded with the appropriate amount of powder to give the required projectile

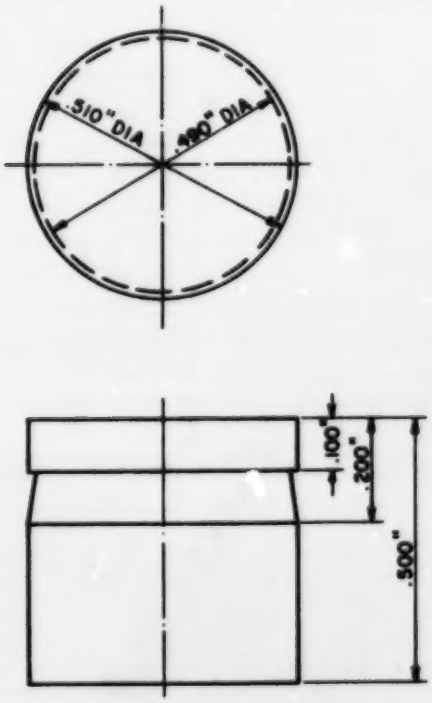

Fig. 7 - Projectile specifications

velocity. To maintain the propellant in intimate contact with the primer, about 2 cm of kapoc is pressed lightly on top of the charge. The projectile is then pressed and crimped in the cartridge using the appropriate dies (9).

Once the round has been fired, the spent primer is pressed out. The cartridge case is then resized and reprimed. It was determined that resizing the neck of the cartridge was easily accomplished with the dies without requiring an annealing process. The cartridge is then reloaded as described above. Figures 8 to 11 show some of these operations.

Fig. 8 - .50 cal round (primer, cartridge, propellant, kapoc, projectile)

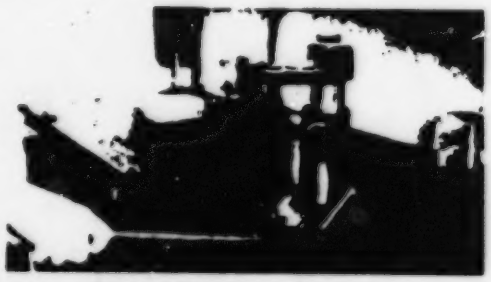

Fig. 9 - Priming the cartridge case

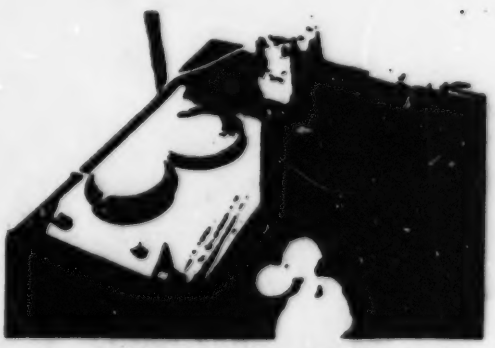

Fig. 10 - Filling cartridge case with powder

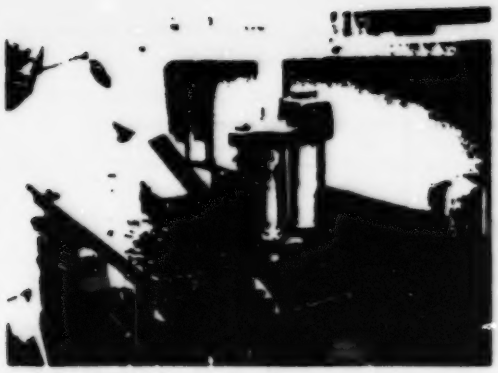

Fig. 11 - Crimping the projectile to the cartridge case

EXPERIMENTAL PROCEDURE

The Explosive Sample

Most explosive samples are usually received in plastic cartridges packed in cardboard boxes. Since the density of an explosive has a great influence on its sensitivity, it is desirable not to disturb the samples from their original package. To accomplish this, 7.6 cm and 8.9 cm diameter cartridges are usually specified since they form satisfactory targets when sliced to length. The explosive sample is carefully packed in a 500 ml cardboard container through which is passed a length of wire used for hanging the sample from the chain in the tank. A schematic of this configuration is shown in Fig 12. For the purpose of authorization, the sample is tested at a temperature that falls in the range 18-22°C. If the sample requires temperature conditioning at this temperature or any other temperature, the explosive is placed in a plastic bag and then placed in the cardboard container. This prevents any loss of liquid. When the correct temperature is reached, the plastic bag is peeled back to expose the front surface of the explosive sample and the cardboard lid is placed on the container. The sample is now ready to be hung in the tank for testing.

Testing Levels

Since the projectile test, as many other tests in the explosives field, is a sensitivity experiment, it is desirable to determine the projectile velocity at which 50% of the explosive samples explode and the other 50% do not. This is denoted as the V-50 point. As with other explosives sensitivity experiments, the logarithm of these levels is usually normally distributed. With this assumption, equally spaced logarithmic testing levels were established. The interval between the levels was established to reflect the estimate of the standard deviation of the test results. Table 1 lists the testing levels presently used for this projectile impact test.

Data Treatment

Statistical analysis is based on a minimum of trials. That is, for N small, where N is the nominal sample size (10). This type of testing is performed in the same manner as the up-and-down method for large N. The testing is performed in the following manner.

1. Estimate the mean test level.
2. Test at the estimated level.
3. Proceed as in common up-and-down test method.
4. Use Table 2 to determine V-50 (50% probability level) and the standard error of the V-50.

From Table 2 it is noted that if a standard error of 0.56σ of V-50 is required, (where it is assumed that the logarithmic interval $d=0.025\sigma$), four more data points are needed after the first reversal of response. This standard error can usually be obtained with a total of ten trials with the present experimental testing method.

As an example, consider the results in the following two tests. Two methods were used to determine the V-50 to demonstrate the effect of extra data. Method #1 is that which is most often used and conforms to the outcomes listed in Table 2 requiring a maximum nominal sample size of N=6. Method #2, can be used to determine V-50 when N is greater than 6. This method corrects the mean value through the constants A and C listed in Table 3 and appearing in the equation,

$$\log(\text{V-50}) = [\Sigma x_i f_i + d(A+C)]/N.$$

Table 1 - Testing levels presently used for projectile testing

Log V	V (m/s)
2.000	100
.025	106
.050	112
.075	119
.100	126
.125	133
.150	141
.175	150
.200	158
.225	168
.250	178
.275	188
.300	200
.325	211
.350	224
.375	237
.400	251
.425	266
.450	282
.475	299
.500	316
.525	335
.550	355
.575	376
.600	398
.625	422
.650	447
.675	473
.700	501
.725	531
.750	562
.775	596
.800	631
.825	668
.850	708
.875	750
.900	794
.925	841
.950	891
.975	944
3.000	1000
.025	1059
.050	1122
.075	1189
.100	1259
.125	1334
.150	1413
.175	1496
.200	1585

Table 2 - Statistical constants from reference (10) used to determine the V-50

SAMPLE SIZE N	Second part of series	k FOR TEST SERIES WHOSE FIRST PART IS O	OO	OOO	OOOO		STANDARD ERROR OF P_{50}
2	×	−.800	−.388	−.378	−.377	O	.88σ
3	×O	.842	.890	.894	.894	O ×	.78σ
	××	−.178	.000	.028	.028	OO	
4	×OO	.289	.314	.315	.315	O××	.67σ
	×O×	−.500	−.429	−.432	−.432	O×O	
	××O	1.000	1.122	1.139	1.140	OO×	
	×××	.194	.449	.500	.506	OOO	
5	×OOO	−.157	−.154	−.154	−.154	O×××	.61σ
	×OO×	−.878	−.861	−.860	−.860	O××O	
	×O×O	.701	.737	.741	.741	O×O×	
	×O××	.084	.169	.181	.182	O×OO	
	××OO	.305	.372	.380	.381	OO××	
	××O×	−.305	−.169	−.144	−.142	OO×O	
	×××O	1.288	1.500	1.544	1.549	OOO×	
	××××	.555	.897	.985	1.000+1	OOOO	
6	×OOOO	−.847	−.847	−.847	−.847	O××××	.56σ
	×OOO×	−1.250	−1.247	−1.246	−1.246	O×××O	
	×OO×O	.372	.380	.381	.381	O××O×	
	×OO××	−.169	−.144	−.142	−.142	O××OO	
	×O×OO	.022	.039	.040	.040	O×O××	
	×O×O×	−.500	−.458	−.453	−.453	O×O×O	
	×O××O	1.169	1.237	1.247	1.248	O×OO×	
	×O×××	.611	.732	.756	.758	O×OOO	
	××OOO	−.296	−.266	−.263	−.263	OO×××	
	××OO×	−.831	−.783	−.753	−.752	OO××O	
	××O×O	.831	.935	.952	.954	OO×O×	
	××O××	.296	.483	.500	.504+1	OO×OO	
	×××OO	.500	.648	.678	.681	OOO××	
	×××O×	−.043	.187	.344	.232+1	OOO×O	
	××××O	1.603	1.917	2.000	2.014+1	OOOO×	
	×××××	.803	1.329	1.465	1.496+1	OOOOO	
		×	××	×××	××××	Second part of series	
		−k FOR SERIES WHOSE FIRST PART IS					

Table 3 - Values for the constants A and C, from reference (10), used to estimate the V-50 when N is greater than 6

$n_O - n_X$	A	C FOR TEST SERIES WHOSE FIRST PART IS OO	OOO	OOOO	OOOOO
5	10.8	0	0	0	0
4	7.72	0	0	0	0
3	5.22	.03	.03	.03	.03
2	3.20	.10	.10	.10	.10
1	1.53	.16	.17	.17	.17
0	0	.44	.48	.48	.48
−1	−1.55	.55	.65	.65	.65
−2	−3.30	1.14	1.36	1.38	1.38
−3	−5.22	1.77	2.16	2.22	2.22
−4	−7.55	2.48	3.36	3.52	3.56
−5	−10.3	3.5	4.8	5.2	5.3
$n_X - n_O$	−A	××	×××	××××	×××××
		−C FOR TEST SERIES WHOSE FIRST PART IS			

As indicated by the results of the two methods, one or two extra data contribute little to the final estimate of V-50.

TEST #1

Log V	Results (X-Fire / O-No Fire)
2.975	X
2.950	O X
2.925	X X X
2.900	O O

Method #1

O-XXXOX

$\log (V\text{-}50) = L + kd$
$= 2.925 + (-0.043)(0.025)$
$= 2.924$
$V\text{-}50 = 840$ m/s

Standard error $= 0.56\sigma$
$= 0.56\ (0.025)$
$= 0.014$

Method #2

O-XXXOXOX

$\log (V\text{-}50) = [\Sigma x_i f_i + d(A + C)]/N$
$= [23.45 + 0.025(-3.30+1.14)/8$
$= 2.924$
$V\text{-}50 = 840$ m/s

Standard error $= \sigma\sqrt{2}/N$
$= 0.025\sqrt{2}/8$
$= 0.012$

L is the last velocity in the series used in the calculations
d is the interval between velocity levels
N is the nominal sample size
k is the constant from Table 2
A and C are constants from Table 3

TEST #2

Log V	Results (X-Fire / O-No Fire)
3.050	X
3.025	O X
3.000	O X
2.975	X X
2.950	O

Method #1

OO-XXXXO

$\log (V\text{-}50) = L + kd$
$= 2.950 + (0.025)(1.917)$
$= 2.998$
$V\text{-}50 = 995$ m/s

Standard error $= 0.56\sigma$
$= 0.56(0.025)$
$= 0.014$

Method #2

$\log (V\text{-}50) = [\Sigma x_i f_i + d(A + C)]/N$
$= [21 + 0.025(-5.22 + 1.77)]/7$
$= 2.988$
$V\text{-}50 = 973$ m/s

Standard error $= \sigma\sqrt{2}/N$
$= 0.025\sqrt{2}/7$
$= 0.013$

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BIBLIOGRAPHY

1. Contestabile, E. and R.R. Vandebeek, Physical testing of explosives with special reference to those of division 1.5, Mineral Research Program, Canadian Explosives Research Laboratory, Report MRP/MRL 78-3 (CF).

2. Contestabile, E. and B. Hendrick, Bullet sensitivity of some slurry explosives, Energy Research Program, Canadian Explosives Research Laboratory, Report ERP/MRL 76-46 (TR).

3. Oehler Research, P.O. Box 9135, Austin, Texas, 73857, USA.

4. Contestabile, E. and T.R. Craig, The CERL 13 mm projectile test and correlation of its results with those from 30.06 projectile tests, Mineral Research Program, Canadian Explosives Research Laboratory, Report MRP/MRL 78-2 (CF).

5. Technical Services Division of Energy, Mines and Resources, Ottawa, Canada.

6. PCB Piezotronics, Inc., 3425 Walden Ave., Depew, New York, 14043-2495.

7. Nagy, E. and E. Contestabile, Apparatus for measuring the velocity of projectiles, Canadian Explosives Research Laboratory, ACEA/MRL 85-68 (TR).

8. Valcartier Inc., C.P. 790 Courcelette, Compte Portneuf, Que., Canada, G0A 1R0.

9. RCBS Inc., P.O. Box 1919, Oroville, California, 95965, (916) 533-5131.